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Distributed Simulation-Based Situational Awareness Experiments

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PREFACE

This document was prepared under Central Research Project (CRP) 1066. It summarizes the results of a situational awareness experiment conducted in the IDA Simulation Center during the spring and summer of 1999. The project team consisted of one member of the Simulation Center, Mr. Timothy M. Stone, and four members of the Systems Evaluation Division: Mr. Richard W. Carpenter, Dr. Dennis F. DeRiggi, Mr. Windsor W. Lin, and Mr. Victor K. Wong.

The authors would like to thank the reviewers of this document, Dr. John M. Gray and Dr. Robert F. Richbourg, whose comments greatly enhanced the quality of our report. We would also like to thank Mr. Mark A. Samuels and Mr. Robert L. Clover for their technical support during the course of the experiment.

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EXECUTIVE SUMMARY

The purpose of this Central Research Project (CRP) is to gain insight into the affect situational awareness (SA) has on small unit engagements and to demonstrate the use of human-in-the-loop (HITL) distributed simulation as an investigative tool. To accomplish these goals, we conducted a two-phased simulation-based experiment consisting of 24 trials per phase in the IDA Simulation Center (SIMCTR). During the experiment, distinct situational awareness conditions were imposed on the participants. Measures of effectiveness were computed for each trial and inferences were made regarding the impact of situational awareness based on these measures.

Trials consisted of simulated company-level armor engagements in which two opposing teams, Red and Blue, attempted to destroy objectives belonging to the opposing team. Each team consisted of two operators controlling 16 M1 main battle tanks simulated by Modular Semi-Automated Forces (ModSAF) version 4.0. The operators on a given team were co-located and cooperated tactically during each of the trials. Opposing sides were located in separate rooms and were not able to view their counterparts' workstations or overhear their conversations.

Two distinct SA conditions were examined. The first, referred to as "visibility level," was the ability of each Blue player to see the units his teammate controlled and the opposing vehicles detected. The second SA condition was the availability to the Blue force of unattended ground sensors. Half the games were conducted with Blue operating at the "high" visibility condition. In the remaining half, Blue players could only display the forces under their direct control. Also, in half the trials, Blue had access to unattended ground sensors; in the remaining half, the sensors were removed. Red always operated under the low levels situational awareness. Thus, Red never had unattended ground sensors and each Red operator could only see the units controlled by his workstation (and the units they detected).

In each of the trials Blue operated under one combination of the situational awareness conditions. Thus four combinations of test conditions were possible. Six

replications of each trial combination were conducted. The experimental was a classical 2^2 factorial design.

At the end of each trial, the armor exchange ratio was computed and the score of the engagement—the difference between the number of objectives lost by Red and Blue—was recorded. Games were considered wins for Blue if the score was positive, wins for Red if negative, and ties otherwise. At the end of the experiment, analysis of variance (ANOVA) was used to determine significant factors and interactions with respect to exchange ratios and point scores. Multinomial logit analysis was applied to determine significant factors and interactions with respect to wins, losses, and ties.

Of the 24 games in the first phase, Blue won 7, Red won only 1, and the remaining 16 were ties. Blue never lost when it had the advantage with respect to either SA factor. Because of the large number of ties, however, the research team decided that we should conduct a second more complex phase of the experiment. This second phase would have more objectives (to reduce the likelihood of ties) and involve slight changes in the initial unit locations to make it easier to unify friendly forces. These changes were made to encourage cooperation between teammates. Additionally, the objectives were moved to more protected positions and a limited number of sensors were placed around each. These changes were made because we felt that defending objectives against small incursions was particularly difficult and may have been a factor in causing so many drawn games.

In the second phase, Blue won 10, Red won 8, and 6 games were tied. Thus the goal of reducing the percentage of ties was attained—but at a cost. In the first phase, outcomes generally reflected test conditions: Blue did better on average when it had an SA advantage. This was not the case in the second phase. Except for the fact that Red never won when Blue enjoyed both SA capabilities, the data revealed no discernable pattern associated with test conditions, trial order, or teams. Apparently the additional objectives in conjunction with the defensive sensor fields introduced too much variability into the scenario or allowed in unforeseen factors that negated the SA advantages.

The analysis of variance and other statistical procedures did not associate any significance to the principal factors in this experiment. Certain interesting trends appeared in the data, however, and these may be worth comment. First, in Phase I (where each team had three objectives to attain and three to defend), players felt strongly that unattended ground sensors were a greater asset than full visibility for the Blue team. The

reasons offered were based on the belief that sensors allowed Blue to follow the progress of the Red force and anticipate its routes of ingress. While visibility allowed Blue to coordinate maneuvers (and provided additional information about Red positions to individual players), this was not considered a critical advantage since players believed they operated largely independently of one another. The data indicated that sensors had the greater impact with respect to point scores, but not with respect to game outcome (win, loss, tie). Neither factor was statistically significant, however.

The second phase (four objectives to attain and defend) is much harder to interpret. The data appear to suggest that the imposition of an additional objective added too much variation to the games for the principal test conditions to have had an effect—except when both factors acted in concert to Blue's benefit. Player explanations for these outcomes related the inability of Blue to outmaneuver Red and defend its own objectives within the timeframe of the game. The advantage given Blue by only one test condition may have been insufficient to overcome the increased burden of additional objectives. When Blue had at most one advantage, Blue won seven games, Red won eight, and three were tied. When Blue had both advantages, Red never won: Blue won three games and three were tied.

Overall conclusions and observations regarding the experiment appear below. They are divided into two parts: observations about the game strategies and implications regarding situational awareness experimentation. Observations regarding the play of the game include the following summary of tactics and players' evaluation of factors affecting situational awareness:

- *Emphasis on Attack*—A consistent emphasis was on attack throughout the trials. Defense was difficult, and even a well-conducted defense might result in the loss of a defended target before the attackers would all be killed. There was also a kind of asymmetry in the test setup that inclined the operators to attack. A battle could not be won without attacking targets in enemy territory. And, although the battle could not be won without a friendly target surviving, this did not necessarily mean that the targets needed to be defended. In particular, if an attacking force met and defeated an enemy attacking force, the enemy might be unable to kill all friendly targets with his remaining tanks, within the time limit.
- *Massed Forces*—A larger force would consistently defeat a smaller force, with a favorable exchange ratio that left it able to defeat a subsequently encountered smaller force.

- *Selective Defense*—The perceived need to mass forces and to attack led to a resource allocation problem: insufficient forces to mass defenders at each site. In many cases, some or even all friendly target sites were left undefended.
- *Attack with Individual Tanks*—While a numerical superiority was a great advantage for tank encounters, only a single tank was required to defeat an undefended enemy target. A common tactic was to send individual tanks to attack targets, in case they were not defended.
- Regarding Situational Awareness Factors, the Players' *General Assessment* Was
  - There was an advantage to having sensors, but it was of more importance to mount a planned attack rather than relying on sensor data to provide a decisive advantage.
  - Visibility is a convenience but not a decisive factor. In contrast to sensors, commanders did not plan their tactics to take advantage of visibility and could recall few instances where it was a perceived factor.

Overall, this experiment did not demonstrate that having an advantage with respect to situational awareness yields a significant benefit in small unit armor engagements. As this report suggests, time constraints and artifacts of the simulation may have driven outcomes. Chapter IV outlines these issues and discusses their effect on the conduct of the games. If this is indeed the case, then redesigning the experiment with these factors in mind, and possibly selecting a different simulation [e.g., Joint Conflict and Tactical Simulation (JCATS)] might show different results.

On the other hand, one could argue that sufficiently many replications of the experiment were conducted to "average out" random anomalous behavior in the simulation (one reviewer took exception to this explanation). Also, with so many replications, consistent artifacts would likely have been recognized and successfully "gamed" by the players. If this is indeed the case, then the experiment calls into question the value of enhanced situational awareness. Continuing this line of argument, the experiment may be demonstrating that either:

1. The SA advantage must be overwhelming (such as one side having complete knowledge of its opponent's position and strength).
2. There is little benefit from the information provided by enhanced SA without the corresponding experience and discipline to make decisions based upon the additional information.

I. BACKGROUND

A. SITUATIONAL AWARENESS AND THE TWO SELECTED FACTORS

1. Basic Issues

This CRP investigates the effect of situational awareness (SA) on the outcomes of small unit engagements. The notion of situational awareness as used in this context means the knowledge a commander has of the forces under his or her control, the neighboring own-side forces not under his control, and the enemy forces within his zone of authority. The level of this knowledge was varied in a series of highly structured human-in-the-loop (HITL) trials in which opposing forces engaged one another in free-play scenarios. The results of this experiment are the subject of this paper.

This research was undertaken, in part, to gain insight into the advantages that digital technology brings to the modern battlefield. Although manifestations of digital technology deserve attention, our focus and emphasis is on situational awareness for several reasons: its importance in the conduct of modern warfare; the potentially tremendous influence of digital technology on SA; and the ease with which factors influencing SA can be modeled in human-in-the-loop simulations. Thus, this research helps to further investigate the combat utility of digital technology that began in 1997 with the Task Force XXI Advanced Warfighting Experiment (TFXXI-AWE). That experiment was conducted to test the Army hypothesis that digital technologies, properly integrated with doctrine, will increase the lethality, survivability, and tempo of the force.

Results of TFXXI-AWE indicated that lethality was not enhanced[1] (with respect to the baseline conventional force), survivability was greater in one out of four missions for the digital unit, and movement rates were comparable for digital and baseline units [Ref. 1]. Because of the ambiguous results of TFXXI-AWE, experiments such as the one

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1 Smaller percentages of digital force M1s and M2s participated in direct fire engagements, but they were equally effective as their baseline counterparts.

described in this paper are important to the extent that they shed light on the combat utility of digital technologies and help address, indeed test, the Army hypothesis.

2. Selected Factors

In this experiment we varied the level of situational awareness that one side (Blue) enjoyed in a force-on-force free-play engagement with an identical opposing Red force. The situational-awareness components that varied involved the level of visibility that the players on the Blue had of their own force and the availability (to Blue) of unattended ground sensors. These factors were selected because it was believed that each would have a measurable effect on the ability of the players ("commanders") to conduct a successful engagement. For example, it was believed at the start of the experiment that allowing Blue players to locate all of their own-side units would enhance Blue's ability to coordinate attacks and defensive maneuvers. Similarly, it was anticipated that unattended ground sensors would enable Blue to locate and react to Red incursions into Blue's territory. Also, these SA components were relatively easy to implement: visibility levels were menu-driven at each workstation; sensors were implemented through a stand-alone sensor simulator that an IDA analyst developed and that we will describe in detail later in this paper.

Situational awareness factors other than the two selected could have been studied along with, or instead of, visibility and sensors. For example, the experiment could have focused on the utility of graphic command overlays or the value of a certain quality of communications in providing commanders with a clear (mental) image of the battlefield. The selected factors were chosen in part because they contribute to the most basic aspect of SA, namely a real-time image of battlefield elements, and in part because they could be simulated using the available tools. And, they demonstrate how distributed simulation can be used to address SA issues.

B. PREVIOUS EXPERIMENTATION

This experiment follows a similar CRP, conducted a year ago, which measured the impact on small unit engagements of two command and control (C2) configurations and levels of visibility of the opposing force. The same structure (factorial design) was adopted for this exercise and the same underlying simulation was selected—Modular Semi-Automated Forces (ModSAF). Twenty-four trials were conducted using the same

group of players who participated in the current experiment. Results suggested that simplified command and control was a modestly significant factor with respect to trial outcomes and favorable exchange ratios. Visibility of the opposing force tracked with favorable outcomes and ratios, but was not significant.

This year's CRP introduced more vehicles for player control, but reduced the number of vehicle types [the earlier experiment used helicopters tanks and infantry fighting vehicles; only tanks and high-mobility multi-wheeled vehicles (HMMWVs) are used in the current exercise]. The previous experiment had a single mobile objective; the current trials have multiple—but stationary—objectives. Also, players this year were assigned particular vehicles to control from the beginning of each trial, whereas last year each team chose how to divide its assets amongst its two members (and could change these assignments during a trial).

Last year's trials were more heavily focused on command and control and consequently entailed a more complex C^2 scheme than the current trials. These are centered on situational awareness exclusively and involve SA aids not used in last year's tests. Specifically, sensor fields were added to the terrain to provide knowledge of opposing units' positions and to serve as aids in the defense of (stationary) objectives.

Taken together, the 2 sets of tests represent 72 human-in-the-loop trials. It is hoped that they provide some evidence for the assertion that HITL-based distributed simulation is a valuable tool for investigating the factors that affect small unit engagements.

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II. DESCRIPTION OF TESTS

A. OVERVIEW AND CONCEPTS

As described in Chapter I, this project investigated the effects of situational awareness on small armor unit combat. The approach was to use man-in-the-loop Distributed Interactive Simulation (DIS). We conducted a series of simulation tests, in which we presented computer operators representing unit commanders, with battlefield information corresponding to different situational awareness levels.

The tests were designed within the constraints of project resources and the simulation environment with the objective of identifying the types of battlefield information that might most affect battle outcomes and that might be seen by operators as being most useful. Most of the variables associated with battle outcomes were controlled, leaving commanders' decisions (when presented with varying situational awareness levels) and random events as the primary determinants of outcomes.

The basic test setup was to use two opposing teams of two operators each, with each operator controlling two M1 platoons (four tanks in each platoon). The vehicles were simulated by ModSAF, a DIS simulator capable of simulating vehicles individually or in aggregate units. Operators' information about the battlefield, and thus his situational awareness, was provided by the ModSAF two-dimensional plan view display and also by a similar display of sensor information generated by the Comprehensive Mine Simulator (CMS). The terrain was a section of the Hunter-Liggett terrain database that had been reflected to create a synthetic symmetric terrain, and the battle objectives (for each side) were to destroy enemy targets at specified locations. These factors are discussed in more detail in Section B. The symmetry of terrain, forces, and commanders' objectives reduced the scenario realism but enabled a strong focus on the effects of differing levels of situational awareness.

B. DISCUSSION OF KEY SIMULATION FACTORS

1. Operator Controls and Situational Awareness Levels

In all of the tests, there were two operators on each side (Blue and Red), with each operator controlling two M1 tank platoons of four tanks each. Each operator had a separate plan-view display (PVD), a two-dimensional map showing features such as roads and terrain contours, overlaid with icons representing each tank under the operator's control. Each unit had a menu of commands associated with it, and the basic method of controlling a unit was to select a command to move to a location and then click the location on the map.

In addition to the vehicles under the operator's control, the PVD showed vehicles within sight of one of the controlled vehicles. Thus, the basic awareness level consisted of knowledge of the commander's vehicles and other vehicles within sight. In each test, the Red force commanders had this basic awareness level. Battlefield information presented to the Blue force commanders varied. Additional information included combinations of two factors:

- "Visibility" consisted of the display of the other Blue vehicles (the two platoons controlled by the other Blue commander) and the vehicles in their sight.
- "Sensors" consisted of a separate PVD, visible to both Blue commanders, that displayed vehicles within sensor fields. The sensor fields consisted basically of the Blue side of the terrain.

2. ModSAF

DIS is a simulation environment in which individual vehicle movements and interactions are simulated in real time. It supports crewed vehicle simulators; for example, the M1 tank simulators use a full crew of four in compartments replicating the M1 interior, using realistic controls and simulated three-dimensional views of the battlefield.

ModSAF is a widely used DIS simulator for a large variety of vehicles, both ground and air. It allows a single operator to control many vehicles, either as a unit (e.g., a platoon) or individually. This "workstation" type of simulator uses a map display (rather than a 3D image that might be seen from one viewpoint) and controls using the

computer keyboard and mouse. The operator enters commands, such as a command to move to a designated geographic point, and can set parameters such as desired speed. ModSAF simulates the vehicle movement, e.g., its specific path and speed, considering factors such as terrain and the vehicle's characteristics. In addition to simulating movement, ModSAF incorporates "behaviors" intended to reflect the actions of the vehicle's crew. For example, specific weapon-firing events are controlled by ModSAF rather than being directly under the control of the computer operator.

ModSAF has proven to be powerful and useful for many purposes. The concept for Semi-Automated Forces (SAF) originally emphasized its role in simulating an enemy who used standard doctrinal behaviors, and friendly forces adjacent to those comprising a higher fidelity simulation using manned simulators. It has also proven useful for analytic studies (such as the one reported here) and larger-scale exercises. It has limitations, however, that derive primarily from the programmed behaviors and from the operator's ability to control vehicles. Limitations noted by the operators in these tests included:

- *Behaviors*—There are some types of complex behaviors that ModSAF does not provide and that are difficult to perform using the available ModSAF commands and tools. Two examples are
  - Finding good defensive positions, that offer partial concealment and good line-of-sight to enemy approaches
  - Conducting a battle involving coordination among vehicles.
- *Control Difficulties*—The basic control mechanism consisted of commanding a platoon to move to a specified point. More complex commands, to follow a specified path, were sometimes given. These commands did not enable complex maneuvering, such as coordinating an attack. A platoon could be "split" and commands issued to individual tanks, but when this was done there was a risk of operator overload as well as difficulties in coordinating the movements of the tanks.

In addition to these difficulties, there were instances of anomalous behaviors. For example, one tank in a platoon would fall far behind or even move in a reverse direction. Or a tank would not fire at an enemy for no apparent reason.

3. Symmetric Analysis

A previous IDA effort investigated the possibility of "symmetric analysis," in which experimental variables would be controlled by using the same or symmetric parameter values for two opposing forces. Some parameters, such as force structures, are easily controlled in simulations. With digitized terrain it was relatively easy to manipulate the data structures to produce a symmetric area by "reflecting" an area along a line. There is some lack of realism in the resulting terrain, e.g., potential loops in roads and rivers and unrealistic abrupt changes along the line of symmetry. Conceptually, perhaps the most limiting and potentially unrealistic aspect was giving the two forces symmetric objectives, with knowledge of the opposing force's starting conditions and objectives. These considerations were analyzed, and small demonstration tests were conducted in earlier studies with the conclusion that symmetric analysis could be a useful analytic tool [Ref. 2].

This study uses the symmetric terrain that was constructed for the earlier studies, a (reflected) portion of Hunter-Liggett with few apparent anomalies. Figure 1 shows the terrain, a square region, 20 km on a side. The Blue and Red tank platoons are approximately 12 km apart and about 15 km from their respective objectives. The objectives are distributed over the upper and lower portions of the terrain in bands approximately 17 km in length. Own-side platoons initial positions are 3-4 km apart. The M1 tank platoons travel slightly under 30 kph in open terrain, thereby requiring nearly 30 minutes to reach objectives when unopposed (operators could, and often did, increase speeds by direct intervention).

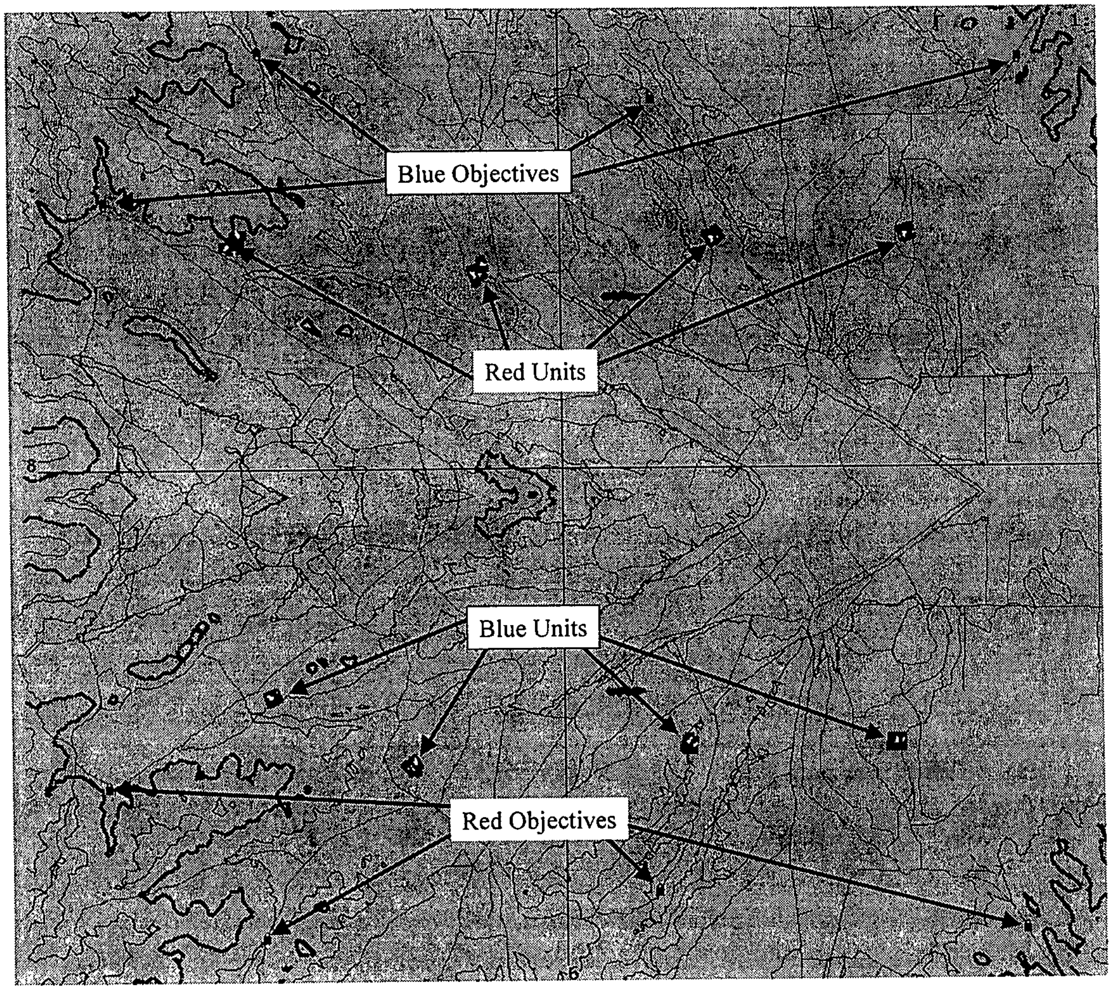

Figure 1. Terrain Layout and Initial Unit Positions

4. CMS Sensors

The Comprehensive Mine Simulator (CMS) was used in these tests to provide simulated sensor data to ModSAF operators.

CMS was developed at IDA originally to simulate and study smart mines, later extended to simulate most types of landmines, and most recently extended to simulate various alternatives to antipersonnel landmines. Primarily for demonstration purposes, it was extended to include stand-alone sensors—"mines" that do not explode, but that use the landmine proximity algorithms to track nearby vehicles and report the results. The simulated sensors are not based on actual sensors, but instead have parameters such as range versus probability of detection. The results are shown on a PVD display similar to

that of ModSAF. For these tests, the sensor displayed a vehicle icon at the detection position.

5. Scenarios

Two series (or phases) of tests were conducted in this study, using slightly different scenarios. Each of them

- Used symmetric terrain.
- Used four platoons of four M1 tanks on each side (Blue and Red), with two platoons controlled by each commander/operator.
- Used symmetric objectives. The objective for each side was to kill enemy stationary vehicles (HMMWVs) at fixed sites, while protecting the friendly HMMWVs.
- Varied the Blue force situational awareness, with runs at all combinations of no awareness, visibility, and sensors (as described in Section B.1).

The two series (phases) differed in:

- The starting locations of the tank platoons.
- The number and locations of the objective HMMWVs.
- The use of small sensor fields around HMMWVs in the second series to aid in their defense.

C. TEST SETUP AND CONDITIONS

1. DIS and the IDA Simulation Center

The situational awareness tests were conducted in the IDA simulation center. In addition to its convenient location, this site was selected because of the availability of a large number of Silicon Graphics workstations and a local area network over which independent ModSAF simulations could interact. Two physically separate areas of the Simulation Center were configured so that opposing teams could communicate with their own members without being overheard by their opponents. Also, workstations were positioned so team members could maneuver forces under their own command, while accessing the sensor simulation at the same time.

In the IDA Simulation Center, ModSAF simulations on separate workstations interact by exchanging protocol data units (PDUs) over the local area network. These PDUs carry information related to the state of the entities being simulated. For example, they convey the position, orientation, and speed of vehicles as well as the types and locations of impact points of rounds fired. The PDUs provide the necessary information to enable separate and distinct simulations to interact in a credible manner.

2. Teams

The project team had four members with ModSAF experience. They became unit commanders and various pairings of these four players made up the six teams in the exercise. Each team-pair remained intact for eight successive games to accommodate all combinations of test conditions (four) as Blue and as Red. After completing a block of eight games, the players were shuffled and new teams were formed.

3. Conduct of the Experiments

Games were typically played in blocks of four with teams alternating between Blue and Red. Thus two sessions were required for a team to complete all possible combinations of situational awareness factors as Red and as Blue. Games were limited to 45 minutes. This time span was selected because it gave players time to implement their tactics without allowing the games to degenerate into long wars of attrition (see Chapter IV, Section B.1 for a discussion of the ramifications of limited game time). Requiring teams to alternate between Blue and Red was intended as much to keep players from becoming bored as it was a test design consideration to reduce the impact of learning.

Games began with each team conducting its own strategy session. These were generally 5-10 minutes in duration. During these sessions, players would decide on their tactics: which avenues of approach to take; how many units to leave in the rear for defensive purposes; where to join forces with their team member; how many tanks to commit to attacking the opponent's armor; which units to send in pursuit of the objectives. Once the respective sides were satisfied with their plans, an umpire would signal the start of the game. A data logger would begin recording PDUs at this point, providing a permanent game record that could be reviewed for analytic purposes.

During the course of the games, the umpire would move between the two teams and, when necessary, lend technical assistance to the players. Typically this would be of

the form of helping to resolve simulation anomalies, such as vehicles that would not move or screens that "froze up."

4. Run Matrices

Each team played together for eight games, four as the Blue team and four as the Red team (alternating between Red and Blue in successive trials). In each case, they played through a complete replication, in (pseudo) random order, of the four possible test combinations: low visibility/low sensors; low visibility/high sensors; high visibility/low sensors; high visibility/high sensors. Thus the experiment was conducted as a randomized complete block 2^2 factorial design where each block was a complete replication of the four test combinations, characterized by the particular team that played Blue for that replicate. Structuring the experiment in this fashion facilitated the ANOVA computations in which each of the factors, their interaction, and the variability due to team differences were accounted for. A total of 24 runs were conducted in each phase. The run matrix for Phase I appears below in Table 1.

Table 1. Run Matrix for Phase I

Run Number	Visibility Level	Sensor Level	Team
1	L	L	A
3	L	H	A
21	H	L	A
23	H	H	A
24	L	L	B
22	L	H	B
4	H	L	B
2	H	H	B
11	L	L	C
7	L	H	C
5	H	L	C
9	H	H	C
14	L	L	D
10	L	H	D
12	H	L	D
6	H	H	D

Table 1. (Continued)

Run Number	Visibility Level	Sensor Level	Team
17	L	L	E
13	L	H	E
19	H	L	E
15	H	H	E
14	L	L	F
20	L	H	F
16	H	L	F
18	H	H	F

The second phase utilized the same players and same experimental design. The order of the runs was somewhat different, however. Again, 24 runs were conducted in six blocks of four trials. The matrix of runs appears in Table 2 below.

Table 2. Run Matrix for Phase II

Run Number	Visibility Level	Sensor Level	Team
12	L	L	A
10	L	H	A
16	H	L	A
14	H	H	A
13	L	L	B
15	L	H	B
9	H	L	B
11	H	H	B
4	L	L	C
8	L	H	C
6	H	L	C
2	H	H	C
7	L	L	D
3	L	H	D
1	H	L	D
5	H	H	D
18	L	L	E
24	L	H	E
20	H	L	E
22	H	H	E
21	L	L	F
17	L	H	F
23	H	L	F
19	H	H	F

Typically, a group of four runs would be executed in one afternoon, a given run lasting between 35 and 45 minutes. Teams would alternate between playing Red and Blue in large part to avoid boredom among the players (players had to physically move between rooms in order to change sides). Two afternoon sessions were required to complete two blocks with half of each block completed in one session. Both phases were conducted under this format. From a statistical perspective it may have been preferable to keep one team playing Blue all afternoon (and one team playing Red) so that the games with a given block in the tables above would have been contemporaneous.

III. RESULTS

A. PHASE I

The outcomes for Phase I trials are presented below in Tables 3 and 4. The columns indicate how many games each side won under the various test conditions. Outcomes were determined by point scores, the number of objectives attained by Blue diminished by the number of objectives attained by Red. The sign of the score determined the winner: positive scores imply Blue is the winner, negative imply Red, and zero indicates a tie. Recall that in Phase I, each side had three objectives to "capture" and three to defend.

Table 3. Phase I—Initial Results

(Visibility – Sensors)	Blue Win	Red Win	Tie
L-L	0	1	5
L-H	1	0	5
H-L	2	0	4
H-H	3	0	3

Table 4. Phase I—Final Results (after re-running the first four trials)

(Visibility – Sensors)	Blue Win	Red Win	Tie
L-L	0	1	5
L-H	2	0	4
H-L	3	0	3
H-H	2	0	4

The first table shows game results after the initial set of 24 runs was complete. The first four runs in this set were rerun because regular team members were unavailable for these runs and substitute players were used. The results after the re-runs appear in Table 4. While both tables suggest that there is mild dependence on the test conditions—

namely some benefit to having sensors or high visibility—neither condition was significant at the 5 percent level.

In each set, Blue won five games when it enjoyed full visibility and four games when it had unattended ground sensors. Games were tried seven times with visibility and eight times with sensors. There is a slightly stronger indication of synergy between factors in the first set (three wins and three ties versus two wins and four ties when both are high). The remainder of this section will focus on the point scores and related measures and their relationship to the test conditions. Results will only be given for the rerun trials and references to the initial set of runs will be omitted.

Point scores for Phase I trials appear below in Figures 2 through 6. As explained above, these scores are the difference in the number of objectives taken by Blue and Red. The first graph in each pair indicates score of each game delineated by test condition: LL connotes low levels of each factor; HL indicates high visibility and no sensors; LH is low visibility with sensors; HH is the high level of each factor. The second chart indicates the total points scored under the specified test conditions. In the latter, each vertex represents the sum of six trials, as there were four different test conditions in the 24 trials (and the experiment followed a balanced design).

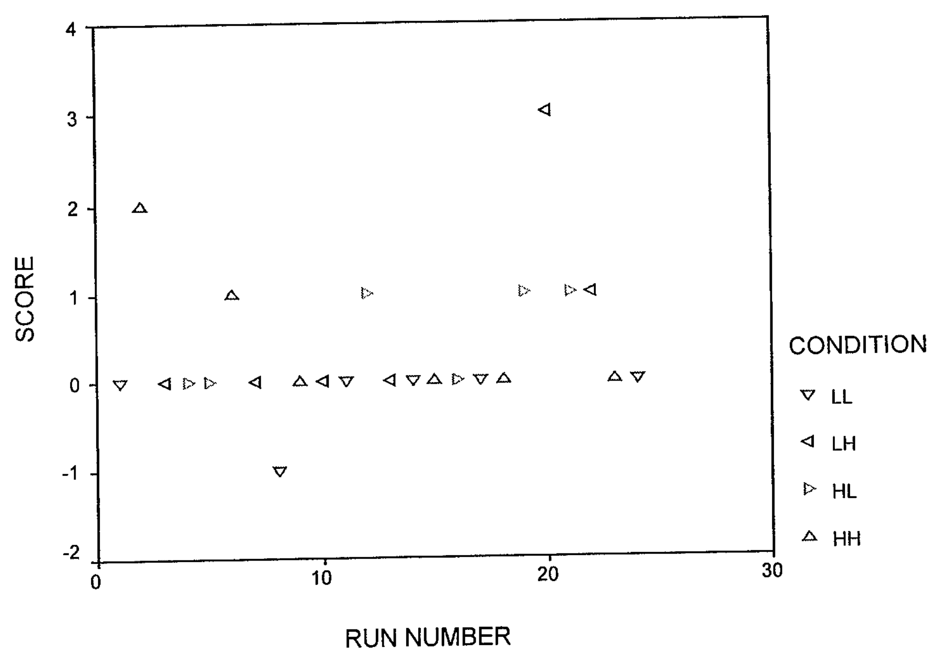

Figure 2. Point Scores vs. Run Number (Final Set)

An observation about Figure 2 made by one of the reviewers related to the early tendency of Blue to win with the high level of both assets. This early advantage disappears rather rapidly, suggesting an adaptive process on the part of Red. While this aspect of Red play was not investigated explicitly, the impact of the run order on outcome is addressed in the ANOVA tables in Appendix A.

By reviewing Figure 3, it appears that sensors have an overwhelming impact on point scores when visibility levels are low. While there is clearly some benefit under these conditions, it may not be substantial as neither factor nor their interaction was significant at the 5-percent level (after controlling for variability due to teams). ANOVA tables for all phases appear in Appendix A.

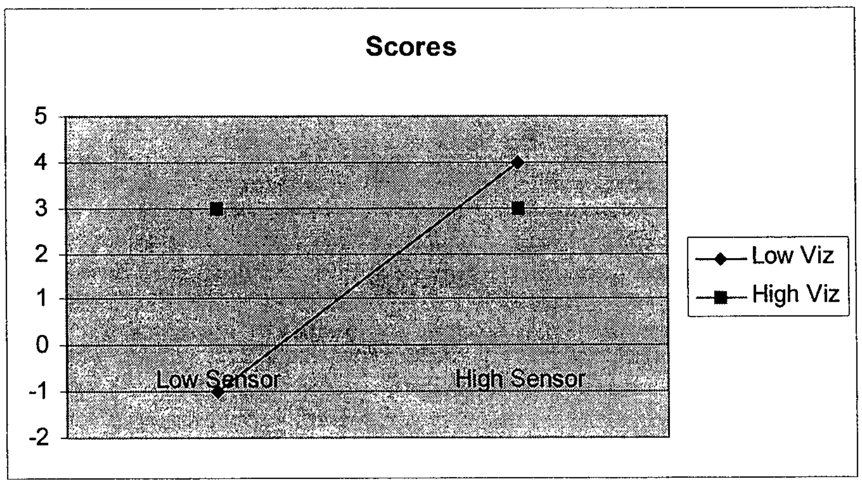

Figure 3. Point Scores vs. Test Condition (Final Set)

Exchange ratios by trial category appear in Figure 4. Recall that engagement victories were not necessarily a goal for either team. If it were possible to gain an objective by sacrificing a platoon of tanks, then Blue or Red would readily make the sacrifice. Nonetheless, the ratio of Red to Blue armor losses is presented because it is a popular measure and one in which interest is often expressed.

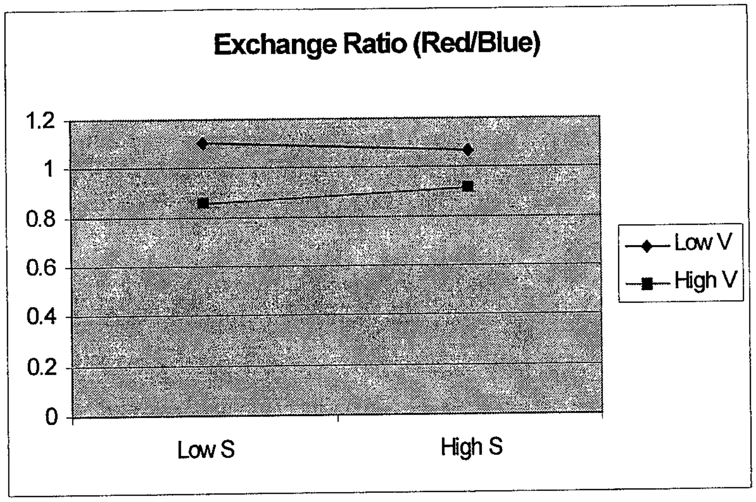

Figure 4. Exchange Ratio (Final Set)

It is interesting to note that the exchange ratio is less favorable for Blue when Blue enjoys greater visibility. ANOVA tables in Appendix A indicate that none of the factors has a significant impact on exchange ratios, however.

The test was conducted with the same four players throughout the entire exercise. These four players were divided into six teams denoted A though F. Team A played B, Team C played D, and E played F. Table 5 presents the wins, losses, and ties for three pairs of teams (where wins and losses refer to the first team in the pair).

Table 5. Team Performance (Final Set)

Team Pairs	Win	Loss	Tie
A-B	1	2	5
C-D	1	2	5
E-F	1	1	6

The six teams performed fairly uniformly throughout the course of the experiment. No real dominance is apparent from Table 5. Because the initial set had team members on the "A" team who did not participate in the remainder of the exercise, the corresponding table for the initial set of runs will not be presented.

While the point scores seemed to indicate that the test conditions were generating results along the lines one would expect (there was some—albeit not significant—Blue

improvement with sensors), the large number of ties was discouraging. These ties seemed to indicate that the game was not sensitive enough to the changes in situational awareness and might never generate pronounced differences in outcomes. As this was central to the research, the scenario was changed, the game was made more complex, and a second set of 24 trials was begun.

B. PHASE II

The new game consisted of one additional objective on each side and a slight repositioning of the tank platoons (symmetry was preserved). The additional objective was added to decrease the probability of tied outcomes; it was thought more objectives would make it less likely that both sides would end up with the same score. The platoons were repositioned to make it easier for the players on a given team to cooperate on maneuvers—thus emphasizing the benefit of high visibility. And finally, sensors were added in the vicinity of each objective on the Blue and the Red sides. The point of these additional sensors was to enhance the ability of each side to defend objectives from their opponent.

Intuition with respect to objectives and ties proved to be correct. The percentage of ties dropped sharply from Phase I to Phase II. But the number of Red victories increased even more dramatically and appeared to transcend any benefit that Blue realized from high visibility and the repositioning of the tank platoons.

Blue won on five occasions when it had full visibility and on five occasions when it had sensors. However, Red won twice when Blue had visibility and four times when Blue had sensors. Red won twice when Blue had no SA advantage. In Phase I, Red only won once. The discussion of why the Red performance is far better in Phase II than in Phase I will be postponed to a later section. For the moment, we will focus on the Phase II results and comment on their significance. One of the more tantalizing outcomes in Table 6 is the failure of Red to win when Blue had both the sensors and high visibility. It appears to suggest that the combined effect gives Blue an advantage that Red cannot overcome. The narrative portion of this paper's analysis will develop the idea more completely. Statistically, the effect is only marginal, however (multinomial log-linear analysis indicates that the interaction between outcomes and visibility is significant at the 5.2-percent level, but no other outcome interaction is significant below the 10-percent level).

Table 6. Phase II Outcomes

(visibility – sensors)	Blue Win	Red Win	Tie
L-L	3	2	1
L-H	2	4	0
H-L	2	2	2
H-H	3	0	3

Figure 5 shows the point scores as a function of run number delineated by test condition. Unlike the companion pictures in Phase I, there is no apparent pattern (i.e., a long horizontal line due to ties) and the dispersion is far greater. In this second phase, the test conditions were weaker indicators of outcome. Some of the more plausible reasons for this lack of association will be discussed in the next few sections.

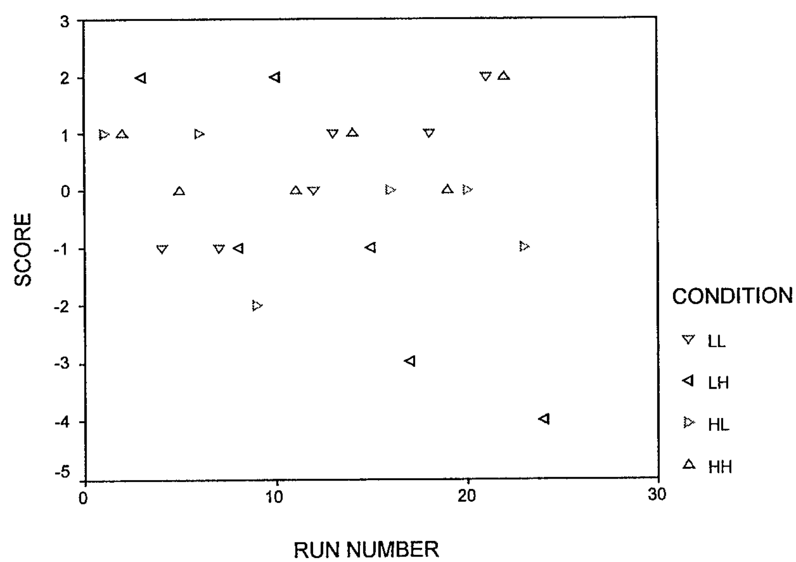

Figure 5. Point Scores vs. Run Number for Phase II

Point scores for the various combinations of test conditions in Phase II appear in Figure 6. These scores show a different form of interaction from Phase I, but, like the earlier phase, suggest the existence of some payoff from the combined effects of sensors and visibility. The difference between the two phases is the large disparity in scores when sensors are available in Phase II—while the corresponding disparity in Phase I occurred under low sensor conditions.

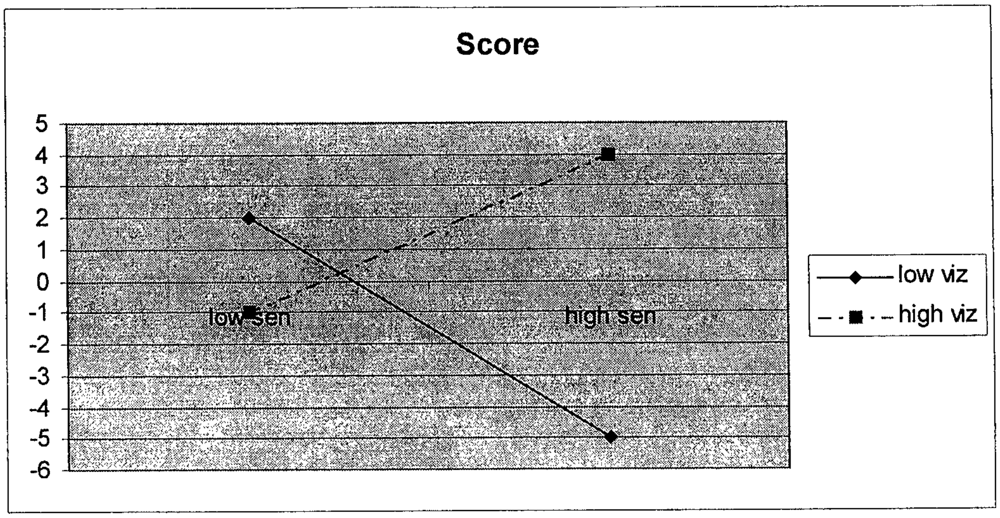

Figure 6. Point Scores vs. Test Condition for Phase II

The ANOVA tables for Phase II in Appendix A indicate that neither of the principal factors or their interaction is significant (the p-value for the interaction was about 17 percent). They also show no significant difference among teams or measurable effect due to the order in which runs were made.

As in Phase I, the exchange ratios (see Figure 7) show no significant sensitivity to test conditions. In fact they are slightly closer to 1.0 for all test conditions than the early set of runs. Somewhat reassuringly, however, they are more aligned with intuition in that higher visibility results in better outcomes for Blue and sensors are an enhancement, at least in low visibility conditions. Again, differences are not significant.

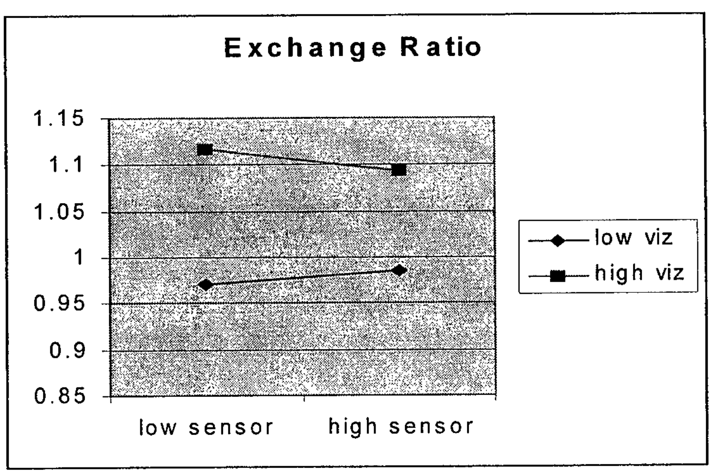

Figure 7. Phase II Exchange Ratio (Red/Blue)

Table 7 below contains the number of wins, losses, and ties accrued by each team. As in the Phase I case, the data are presented for the pairs of teams that played one another. Team performance appears less uniform than was the case in the earlier phase. Indeed team A dominates team B and team E appears stronger than F. Multinomial logit analysis showed no significant interaction between pair and outcome, however (regardless of the order of the individual teams in the pairings: e.g., B-A instead of A-B, etc). Also, recall that the ANOVA for point scores did not show team variability to be a significant factor.

Table 7. Phase II Blue Team Performance

Team Pairs	Win	Loss	Tie
A-B	4	1	3
C-D	3	4	1
E-F	4	2	2

IV. OPERATOR ASSESSMENTS

During the course of the experiments the four operators changed their tactics in response to their perceptions of tactics that worked, tactics that their opponents were likely to pursue, ModSAF characteristics and capabilities, and simply things they wanted to try. The operators discussed tactics among themselves, particularly team members. The periodic changes in team composition thus encouraged the development of tactics. Following the tests, the operators discussed their assessments of what had been learned, specifically how to account for the outcomes, and two operators reviewed the recorded data files for most of the runs for additional insights. The following sections discuss operators' assessments of factors that affected battle outcomes or tactical choices.

A. SITUATIONAL AWARENESS

The test objective was to assess the value of situational awareness, and the tests were designed so that the only functional difference between the two sides in any run was a different level of situational awareness. The operators were always aware of the difference, and planned tactics accordingly.

In general, the operators regarded "visibility," the sharing of data between the two operators on one side, as not being particularly useful. "Sensors," having knowledge of sensor detection of tank movements on the friendly side of the battlefield, was regarded as useful and to a significant extent affected the tactics chosen by each side. At a few points during the tests, particularly following the first set and at about the midway point of the second set, the operators were told that the interim results showed that visibility was a more important advantage than sensors. At the time, the operators regarded this as an anomaly that resulted partly from chance and partly from inexperience in using the sensor data. Initially, there was a tendency for Blue to attempt to use sensor data by holding his forces in his own area, where sensor data were available, and to wait for Red to attack. The game dynamics were such that Blue might be unable to engage Red with superior force, or that Red would be able to kill the Blue objectives even if he lost more tanks than Blue. By the end of the tests, the general assessment was that there was an

advantage to having sensors, but that it was more important to mount a planned attack rather than to rely on sensor data to provide a decisive advantage. Sensor data could, in some cases, be used to help defend particular sites, and in particular it prevented Red from infiltrating the Blue side undetected.

Post-test discussions and the review of test recordings expanded this assessment. The review indicated that chasing the enemy was seldom successful, and that there were many instances where Blue did this. Typically, Blue forces would be deployed forward of the sites it was defending, Red would attack along a path not directly through the Blue force; Blue would fail to interpose forces directly in Red's path and would end up chasing Red. At least one operator deliberately tried to delay intercepting Red with the thought that there would be an advantage in attacking Red's flanks. Red would usually kill the objective, and sometimes would proceed to another objective with Blue still chasing. Without sensor knowledge (except within 1 km of his sites) Red defenders would stay close to its defensive sites and intercept any Blue attackers. This tactic was more successful.

The effects of visibility remain a mystery to the operators. Visibility has two aspects, that all Blue forces are visible to each Blue commander and that all Red forces seen by any Blue vehicle are visible to each Blue commander. Plausibly, each aspect could aid Blue coordination. However, Blue forces attempting to coordinate their actions were generally in sight of each other so that visibility provided little additional own-force information (just the locations of the out-of-sight forces, e.g., remote defensive forces). And, commanders without visibility used voice to tell their partners about enemy sightings. At the end, the operators subjective assessment is that visibility is a convenience but not a decisive factor. In contrast to sensors, commanders did not plan their tactics to take advantage of visibility and could recall few instances where it was a perceived factor.

B. DESIGN ISSUES

As described earlier, these tests were designed to control as many variables as possible, while examining different levels and types of situational awareness. The tests were also constrained by the simulation environment and the scope of the effort. Some of the results, both in terms of the effectiveness measures and the tactics that were

employed, were affected by the test design in unforeseen ways. Factors identified by the operators included:

- The time limit
- Effectiveness measure
- The sensor field coverage.

1. The Time Limit

A time limit of 45 minutes was used for all trials. It was selected initially as sufficient to allow a typical run to be played to completion, and this was generally the case for the first set of runs. In this set each side's forces were widely separated and there were few attempts to unify them, so that in most runs there were separate battles on the east and west parts of the terrain. There was more than enough time to fight a battle and reach the opposition objectives. In fact, a common tactic, particularly for Red when facing a situational awareness disadvantage, was to wait on its side of the terrain and launch an all-out attack when there was just enough time to reach the Blue objectives. If Blue used all its forces to defend, it would not have time to reach the Red objectives. Thus Blue could not afford to use all its forces in defense, and Red's attack would most often be successful. A common outcome was a tie, with all objectives killed.

In the second set of trials there was one more objective, the objectives were somewhat harder to reach, and each side's forces were not widely separated. This led to more tactical variations, most of which involved some degree of unification or coordination of forces. In many runs, a side would attack in one sector and attempt for elements of this single attacking force to reach all objectives. There was not enough time to do this in a deliberate fashion (by gathering a unified force and having it attack each objective in turn) and many runs ended with a race against time to reach an objective.

Thus, in each set the time limit resulted in "gamesmanship" and affected tactics. In the second set, it was one of the reasons Blue could not afford to wait on his side of the terrain to take advantage of the sensor field.

2. Effectiveness Measure

Although tank kills were recorded and are presented in Chapter III, the objective for each side was to kill the opposition stationary HMMWV targets while defending the

friendly targets. This led to a willingness to sacrifice tanks and tactics such as breaking off from tank battles to attack the objectives. Even if a defending force would win a victory in terms of tank exchange, a single enemy breaking through the defense could kill the objective target. A common tactic was to send a single tank against a target, in the hope that it would be undefended or if defended that the attacker could kill the objective before being killed. Because of the advantage of massed forces (discussed in Section C.1), a force would almost never attempt to defend all of its targets.

3. The Sensor Field Coverage

When it was used, the sensor field covered only the Blue side of the terrain and thus was only helpful for defense. However, the battlefield geometry was such that the targets on the Blue side were widely spaced compared to their distance from the Blue-Red dividing line, so that the sensors did not provide enough warning for a centralized Blue force to engage an invading Red force before it reached a target.

C. COMBAT CHARACTERISTICS

Many combat capabilities affected battle outcomes, e.g., weapon effectiveness, detection range, etc. The characteristics discussed in this section are those identified as affecting tactical choices. One reason for this discussion is that these characteristics may in part be artifacts of the simulation, scenario, or test design, so that they may have affected tactical choices in unrealistic ways.

1. Massing Forces

A numerical superior force had a greater advantage than might be expected. No specific tests were made, but as an estimate two platoons (eight tanks) might be expected to defeat one platoon (four tanks), killing all four of the enemy while losing no more than one or two tanks. Battles happened very quickly, so that a disorganized force that did not get all of its tanks into the battle at the same time was at a severe disadvantage.

2. Defending

Arranging tanks in good defensive positions was very much a guessing game. There seemed to be two factors involved: intervisibility and motion.

Intervisibility was the more important factor, particularly in hilly terrain. Tanks placed near a defended target might not see attackers until after the attackers saw the target, or a group of attackers might see the defenders one at a time and have a numerical advantage over each. The simulation environment provided no good way to quickly find partially concealed positions with good sight lines. Presumably, this was an important reason that placing defenders very close to the defended target was a good tactic.

Overall, the estimate was that a moving attacking force has a slight advantage over a stationary defensive force, and operators would generally move the defending force towards the attackers during combat.

D. SUMMARY OF FAVORED TACTICS

A number of elements were commonly used as parts of a strategy for any given run, including:

- *Emphasis on Attack*—A consistent emphasis was on attack throughout the trials. Defense was difficult, and even a well-conducted defense might result in the loss of a defended target before the attackers would all be killed. There was also a kind of asymmetry in the test setup that inclined the operators to attack. A game could not be won without attacking targets in enemy territory. And, although the game could not be won without a friendly target surviving, this did not necessarily mean that the targets needed to be defended. In particular, if an attacking force met and defeated an enemy attacking force, the enemy might be unable to kill all friendly targets with his remaining tanks, within the time limit.
- *Massed Forces*—A larger force would consistently defeat a smaller force, with a favorable exchange ratio that left it able to defeat a subsequently encountered smaller force.
- *Selective Defense*—The perceived need to mass forces and to attack led to a resource allocation problem: insufficient forces to mass defenders at each site. In many cases, some or even all friendly target sites were left undefended.
- *Attack with Individual Tanks*—While a numerical superiority was a great advantage for tank encounters, only a single tank was required to defeat an undefended enemy target. A common tactic was to send individual tanks to attack targets, in case they were not defended.

1. Tactics in the First Trial Phase

In this phase the two commanders for a given side seldom tried to unify their forces, and most runs became separate battles to the east and west of the terrain. There were variations in the attack route and in the size of the attacking force.

A tactic that became common for Red to use when Blue had a situational awareness advantage was to position his forces near the center of the terrain and to attack with all of them with about 20 minutes left in the run. This conceded the loss of all his targets but usually resulted in killing all Blue targets. The thought was that a tie was sufficient when facing the situational awareness disadvantage.

2. Tactics in the Second Trial Phase

The tactics used in the second phase were more varied than those in the first. In most runs substantial cooperation occurred between the two commanders for a side. It was most common for the western commander to send a platoon to join an attack in the east. The attack might include one or both eastern platoons. In some cases, the other western platoon would cross to defend the eastern targets. Less common were cases when a unified force would attack near the center or in the western parts of the terrain. Near the end of the set a few cases occurred in which a side attacked with all four platoons in the east-central area. The thought was that, after defeating the opposing force in this area, some of the attacking force would drop back to defend the eastern targets and the rest would continue to the opposing targets.

V. CONCLUSIONS AND RECOMMENDATIONS

This experiment did not demonstrate that having an advantage with respect to situational awareness yields a significant benefit in small unit armor engagements. As this report suggests, time constraints and artifacts of the simulation may have driven outcomes. Chapter IV outlines these issues and discusses their impact on the conduct of the games. If this is indeed the case, then redesigning the experiment with these factors in mind, and possibly selecting a different simulation (e.g., JCATS), might show different results.

On the other hand, one could argue that sufficiently many replications of the experiment were conducted to "average out" random anomalous behavior in the simulation. Also, with so many replications, consistent artifacts would likely have been recognized and successfully "gamed" by the players. If this is indeed the case, then the experiment calls into question the value of enhanced situational awareness. Continuing this line of argument, the experiment may be demonstrating that either:

- The SA advantage must be overwhelming (such as one side having complete knowledge of its opponent's position and strength).
- There is little benefit from the information provided by enhanced SA without the corresponding experience and discipline to make decisions based upon the additional information.

The time and resources available to this CRP do not permit the development of either of these hypotheses. Future research involving experiments of the elementary type conducted here might shed light on the first, however. The second is arguably more subtle and may require a level of insight into tactics and procedures only found in individuals with extensive military experience. More sophisticated experiments involving individuals with the relevant training are probably necessary to successfully address the second hypothesis.

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Appendix A

ANOVA TABLES

Appendix A
ANOVA TABLES

Table A-1. Phase 1A—Tests of Between-Subjects Effects

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	XRATIO	7.588	9	0.843	1.079	0.433
	SCORE	5.479	9	0.609	0.865	0.575
Intercept	XRATIO	4.387E-02	1	4.387E-02	0.056	0.816
	SCORE	1.081	1	1.081	1.535	0.236
VIZ * SENS	XRATIO	1.493E-02	1	1.493E-02	0.019	0.892
	SCORE	9.393E-02	1	9.393E-02	0.133	0.720
VIZ	XRATIO	0.978	1	0.978	1.252	0.282
	SCORE	0.667	1	0.667	0.947	0.347
SENS	XRATIO	0.604	1	0.604	0.773	0.394
	SCORE	1.748	1	1.748	2.483	0.137
TEAM	XRATIO	5.254	5	1.051	1.345	0.302
	SCORE	2.616	5	0.523	0.743	0.604
RUN ORDER	XRATIO	0.649	1	0.649	0.831	0.377
	SCORE	1.813	1	1.813	2.575	0.131
Error	XRATIO	10.939	14	0.781		
	SCORE	9.854	14	0.704		
Total	XRATIO	51.307	24			
	SCORE	18.000	24			
Corrected Total	XRATIO	18.527	23			
	SCORE	15.333	23			

Ratio R Squared = 0.410 (Adjusted R Squared = 0.030)

Score R Squared = 0.357 (Adjusted R Squared = -0.056)

Table A-2. Phase I B—Tests of Between-Subjects Effects

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	SCORE	4.425	9	0.492	0.615	0.766
	XRATIO	7.368	9	0.819	1.028	0.465
Intercept	SCORE	0.283	1	0.283	0.353	0.562
	XRATIO	3.824	1	3.824	4.803	0.046
VIZ * SENS	SCORE	1.024	1	1.024	1.280	0.277
	XRATIO	3.931E-02	1	3.931E-02	0.049	0.827
VIZ	SCORE	0.375	1	0.375	0.469	0.505
	XRATIO	0.997	1	0.997	1.252	0.282
SENS	SCORE	1.058	1	1.058	1.322	0.269
	XRATIO	0.540	1	0.540	0.678	0.424
TEAM	SCORE	1.486	5	0.297	0.371	0.860
	XRATIO	4.434	5	0.887	1.114	0.397
RUN ORDER	SCORE	9.135E-02	1	9.135E-02	0.114	0.740
	XRATIO	0.385	1	0.385	0.483	0.498
Error	SCORE	11.200	14	0.800		
	XRATIO	11.149	14	0.796		
Total	SCORE	19.000	24			
	XRATIO	51.555	24			
Corrected Total	SCORE	15.625	23			
	XRATIO	18.517	23			

Score R Squared = 0.283 (Adjusted R Squared = -0.178)

Ratio R Squared = 0.398 (Adjusted R Squared = 0.011)

Table A-3. Phase II. Tests of Between-Subjects Effects

Source	Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	SCORE	15.063	9	1.674	0.572	0.798
	XRATIO	2.249	9	0.250	1.352	0.296
Intercept	SCORE	1.838	1	1.838	0.629	0.441
	XRATIO	2.101	1	2.101	11.371	0.005
VIZ * SENS	SCORE	5.474	1	5.474	1.872	0.193
	XRATIO	5.153E-03	1	5.153E-03	0.028	0.870
VIZ	SCORE	1.251	1	1.251	0.428	0.524
	XRATIO	4.149E-02	1	4.149E-02	0.225	0.643
SENS	SCORE	0.167	1	0.167	0.057	0.815
	XRATIO	7.019E-06	1	7.019E-06	0.000	0.995
TEAM	SCORE	4.951	5	0.990	0.339	0.881
	XRATIO	1.906	5	0.381	2.062	0.131
RUN ORDER	SCORE	1.896	1	1.896	0.648	0.434
	XRATIO	0.251	1	0.251	1.356	0.264
Error	SCORE	40.937	14	2.924		
	XRATIO	2.587	14	0.185		
Total	SCORE	56.000	24			
	XRATIO	34.675	24			
Corrected Total	SCORE	56.000	23			
	XRATIO	4.836	23			

Score R Squared = 0.269 (Adjusted R Squared = -0.201)

Ratio R Squared = 0.465 (Adjusted R Squared = 0.121)

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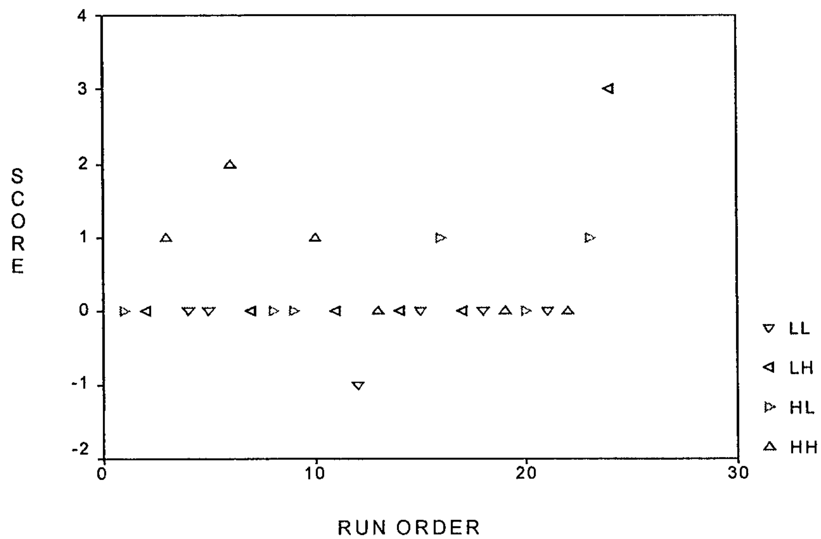
Appendix B

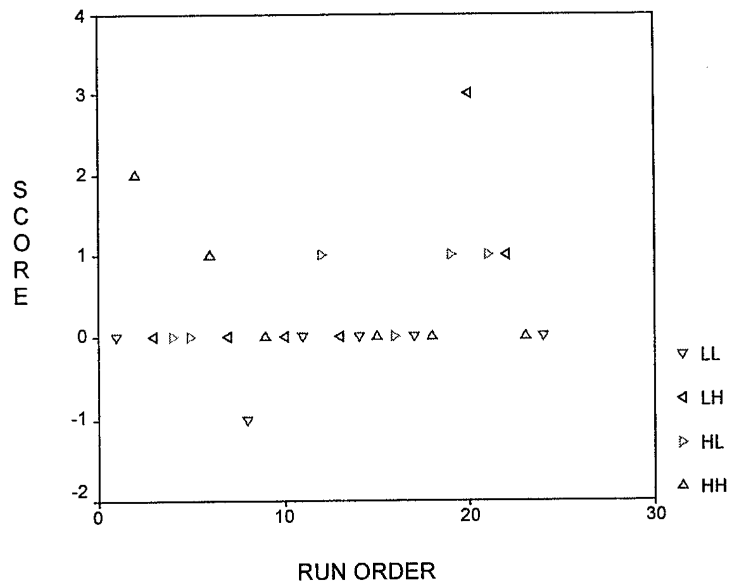
SCORES VS. RUN ORDER

Appendix B
SCORES VS. RUN ORDER

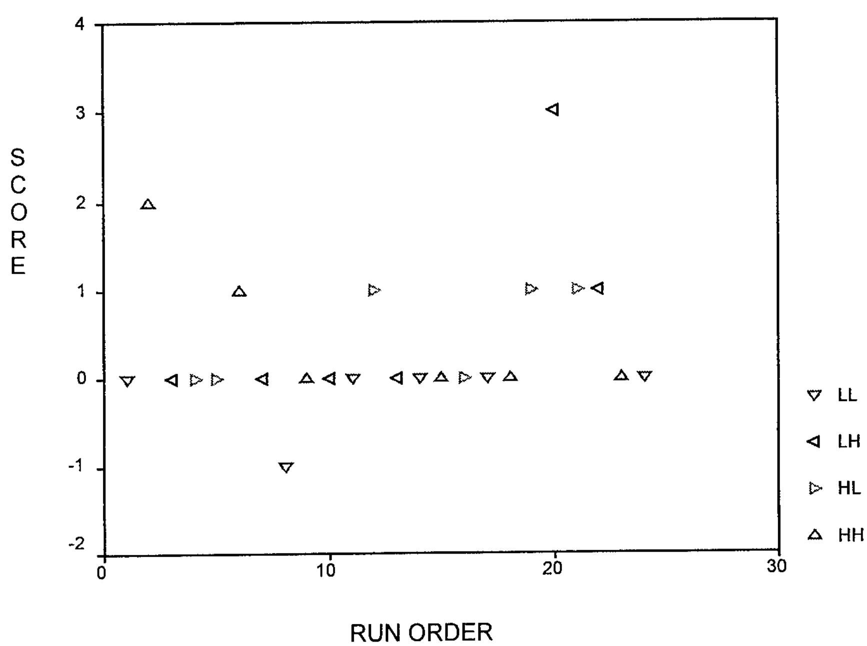
Phase I A



Phase I B



Phase II



Appendix C

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Appendix C
REFERENCES

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Appendix D

GLOSSARY

Appendix D
GLOSSARY

ANOVA	analysis of variance
C2	command and control
CMS	Comprehensive Mine Simulator
CRP	Central Research Project
DIS	Distributed Interactive Simulation
HITL	human in the loop
HMMWV	high-mobility multi-wheeled vehicle
km	kilometer
kph	kilometers per hour
ModSAF	Modular Semi-Automated Forces
PDU	protocol data unit
PVD	plan-view display
SA	situational awareness
SAF	Semi-Automated Forces
SIMCTR	Simulation Center (at IDA)
TFXXI-AWE	Task Force XXI Advanced Warfighting Experiment

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Appendix E

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13. ABSTRACT *(Maximum 200 words)*

Situational awareness is an issue of growing interest and importance in analyses of the modern battlefield. This report summarizes the results of a 2^2 factorial experiment in which two components of situational awareness were varied in a free-play interactive wargame. The two components were battlefield visibility (as presented on a workstation display) and the availability of unattended ground sensors. Half the trials were conducted with all Blue forces on the battlefield visible to all members of the Blue team; half were conducted with (Blue) players' visibility restricted to those units under his direct command. Similarly half of the trials were played without sensors. Analysis of variance and log-linear analyses indicated that neither of these factors was significant, suggesting that the complexity of the engagements overwhelmed their impact.

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Situational Awareness, Distributed Simulation, Unattended Ground Sensors, Factorial Design, Analysis of Variance, Log-linear

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